

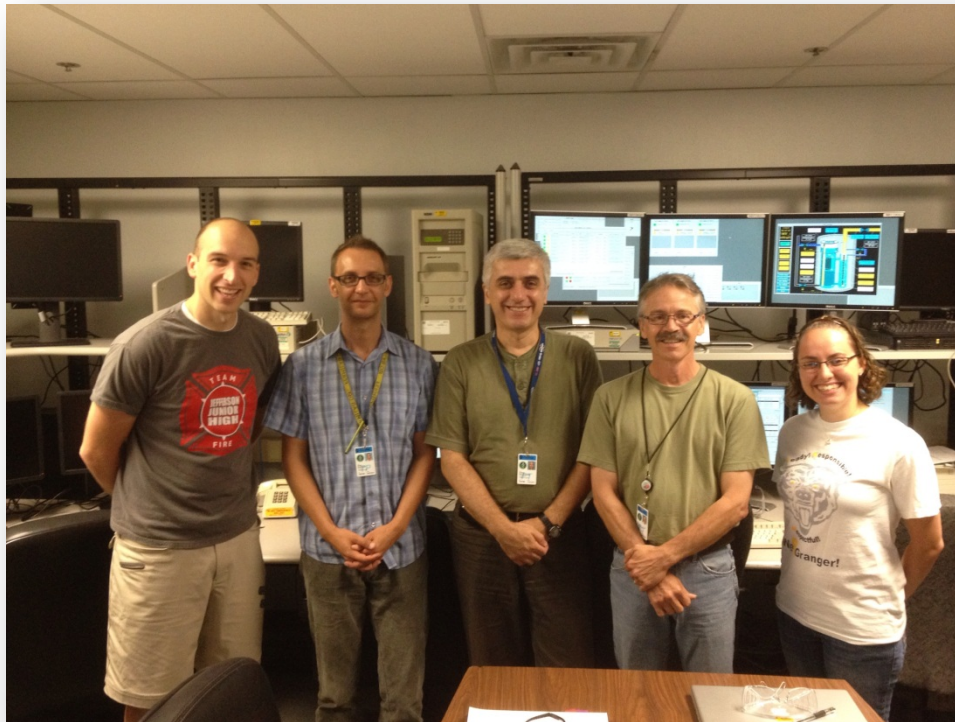
Fermilab's TRAC Summer Experience

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Assignment

- Technical Division
 - Magnet Systems Department
 - Measurement & Analysis Group
 - Marc Buehler; Guram Chlachidze; Michael A. Tartaglia



Big Picture

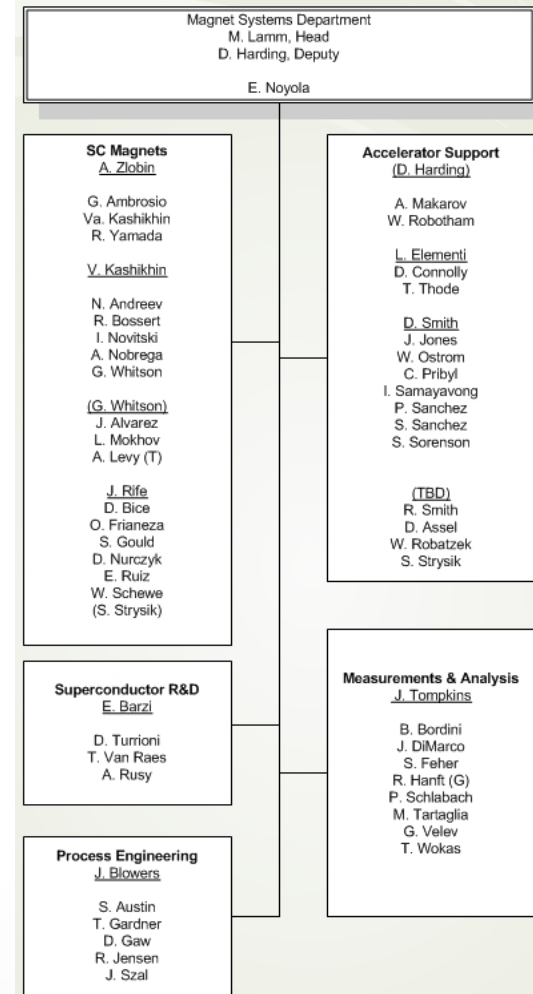
- Magnet Systems
 - “Magnet Systems Department (MSD) is the key executor of the Fermilab magnet program. We provide expertise in all areas of magnet and conductor R&D by developing, evaluating and improving existing technologies for current or future accelerators, along with the development of new technologies in the areas of superconducting and other structural materials and components. The area of our activity covers magnet design, fabrication, test and analysis.”

– Magnet Systems Department Website



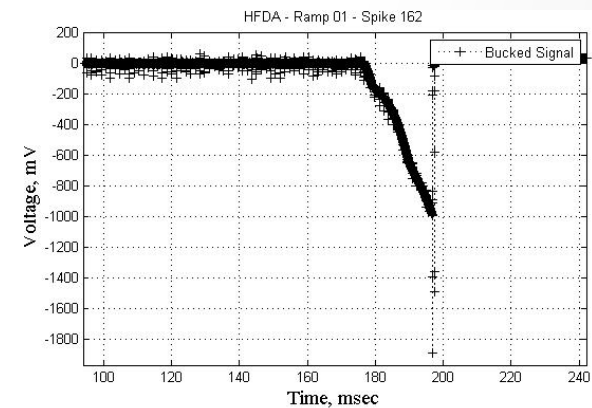
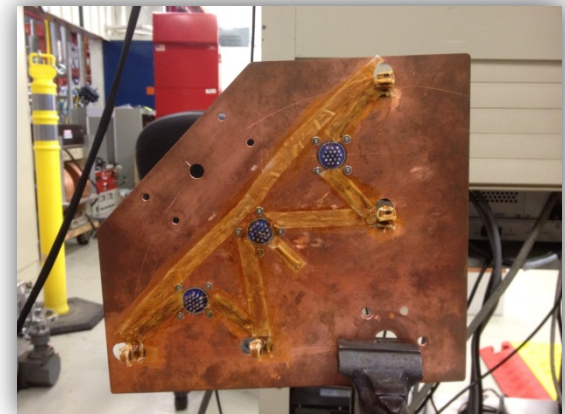
Measurement & Analysis

- Bridge between Test Department and Magnet R&D groups
 - Develop testing plan
 - Analysis of relevant data
- Design and Development of Magnetic Measurement Instrumentation



Role

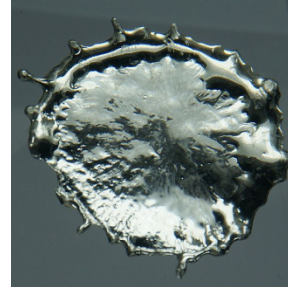
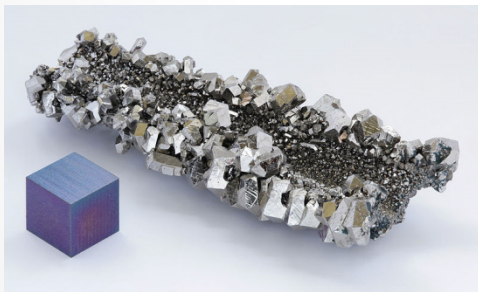
- Two Primary Roles
 - Hall Probe Calibration
 - Set-up calibration magnet along with associated hardware and software
 - Analyzed several Hall probes, ensuring accurate measurement and analysis in “real” experimental situations
 - Voltage Spike Detection Data Analysis
 - Organized files, processed data, and analyzed significant events



New Technology

- Superconducting Niobium Tin (Nb_3Sn) Magnet
 - Nb_3Sn is “superconducting at a higher temperature than niobium titanium and therefore has a greater tolerance for heat; it can also be superconducting at a magnetic field more than twice as strong.”

- Paul Preuss



Training the Magnet

- “A magnet is literally trained to remember its superconducting temperature range, and the best magnet is the one with the best memory.”

- Mike Perricone



Cooling → Ramping → Quenching



Thermal Cycle

-- If Plateau is achieved

Training the Magnet

- Cooling – Liquid Helium is used to achieve temperatures between 1.9K & 4.6K
- Ramping - Ramp up the current & wait for a quench
 - Quench - a superconducting magnet begins to quench when a small area begins to resist current flow and generates heat
- Repeat - After cooling to 1.9 Kelvins, a magnet is subjected to several quenches until it reaches an acceptably high current and field.
 - Each quench event takes an hour or more for recovery, with the cryogenic system dispersing the heat released into the magnet and the liquid helium.
- The amount of current one is able to apply to the magnet increases after subsequent quenches
 - This is due in part to mechanical shifting of the coil – which works out any weak spots within the arrangement
 - Once the coil has settled, the same weak spot is not there and you are able to get a higher current – eventually you reach a point of no further improvement and you hope this is where the magnet is designed to perform

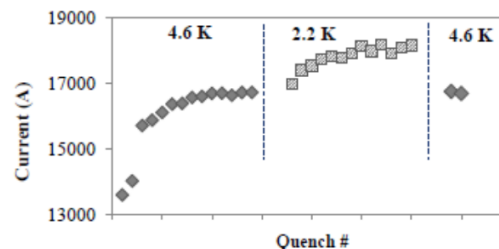


Fig. 6. HQM02 training quenches at 4.6 K and 2.2 K.

- Thermal Cycle – Magnet is brought to room temperature and cooled back down
 - Now another quenching is staged. If the magnet achieves a current beyond the target set for operating the accelerator, the magnet passes the test.

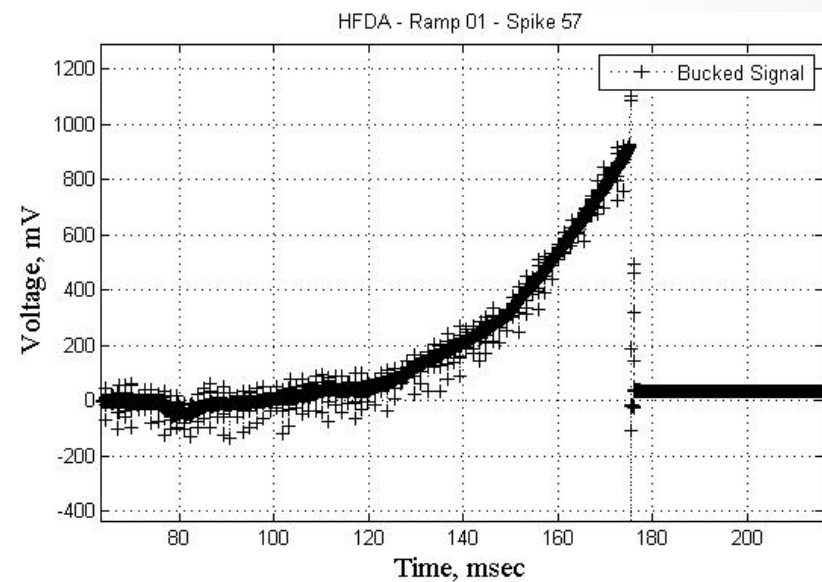
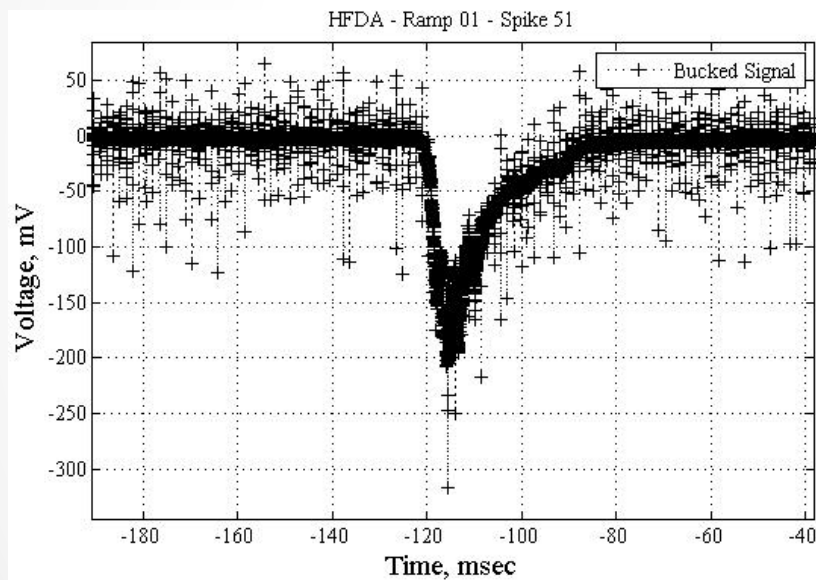
Quenching?

- Quenching is the result of a superconductor becoming resistive
 - Resistance means heat & heat means the liquid helium surrounding the magnet will be turned to gas
- According to Scientists the characteristics a good quench should have.
 - First, for safety purposes, a quench should occur at high current.
 - Second, for improved efficiency of the magnet, there should be no non-quenching voltage spikes at low current.



VSDS

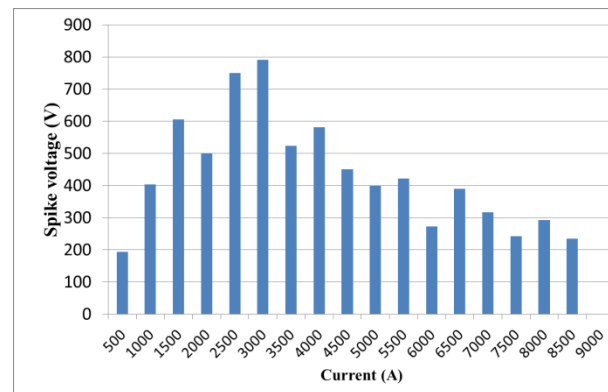
- Voltage Spike Detection System
 - Distinguishing the difference between “noise” and significant events



VSDS

- Voltage Spike Detection System

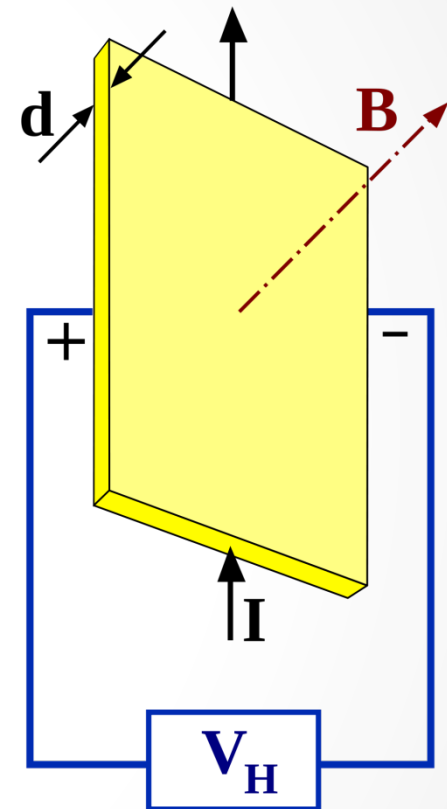
- Although Nb₃Sn theoretically offers a greater critical applied field at greater critical current densities than NbTi, the performance of Nb₃Sn magnets is thought to be limited by thermo-magnetic instabilities
 - Also known as flux jumps - which manifest themselves as distinct transient spikes in coil voltages



- There is a balance between protecting the magnet from possible damaging resistivity and allowing the magnet to ramp without quenching immediately.
 - The voltage spike detection system allows scientist to analyze the events that regularly occur during the ramping cycle and make protective boundaries around those regular occurrences.

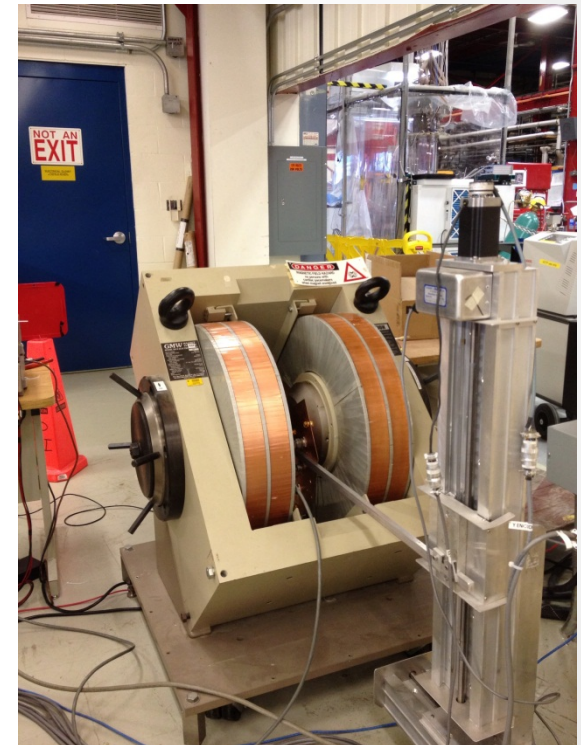
Hall Probe

- What is it?
 - A Hall Probe is able to turn magnetic field (something that we can not see) into a value, in this case volts.
 - Hall Effect - is the production of a voltage difference (the Hall voltage) across an electrical conductor, transverse to an electric current in the conductor and a magnetic field perpendicular to the current



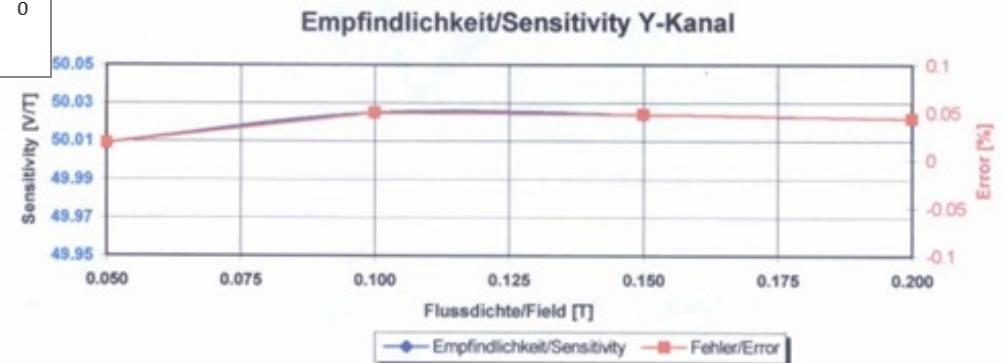
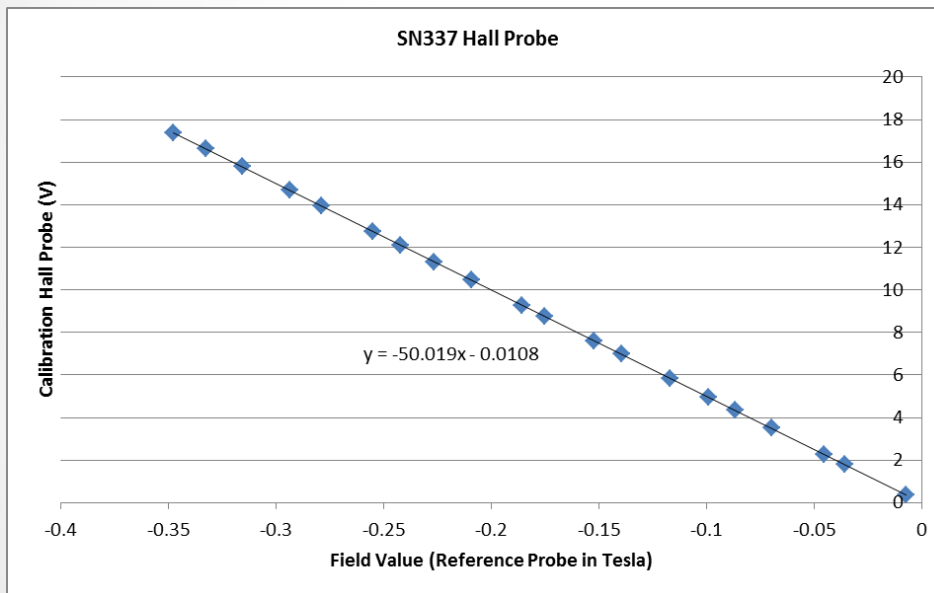
Calibration

- Calibrating Hall Probes
 - Ensures accuracy of instrumentation
 - Probes had not been used for 3 to 5 years
 - Comparative
 - NMR & other Hall probes were often used as a reference in determining field
 - Manufacturers provide calibration data



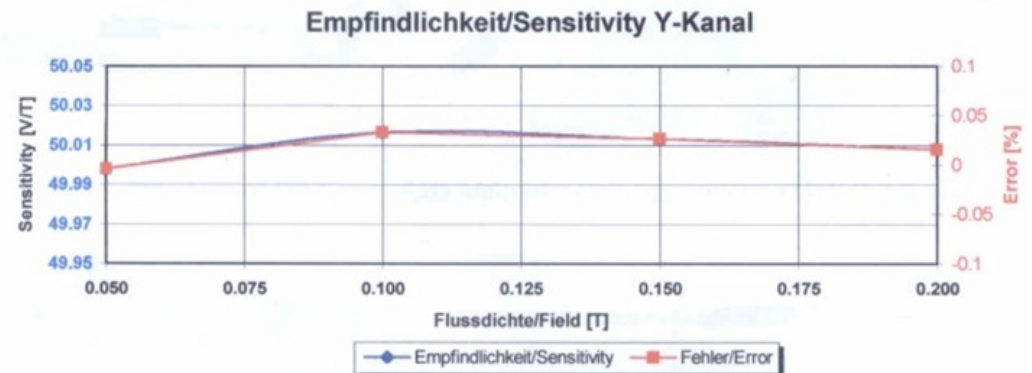
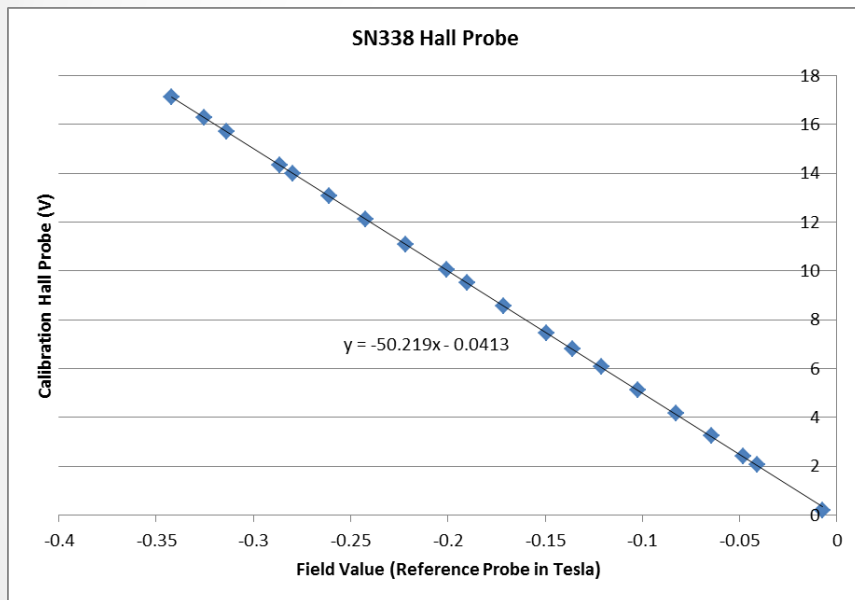
Findings

- V/T Ratio
 - The ration between voltage and field were as expected at 50.019.
 - Manufacturers calibration data suggests a ratio between 50.01 and 50.03 should be expected.



Findings

- V/T Ratio
 - Similarly the ratio between voltage and field for SN338 was 50.219.
 - Manufacturers calibration data suggests a ratio between 50.00 and 50.02 should be expected.



Findings

- Hall Probe Array
 - Uncertainties from manufacture at 1%
 - Additional uncertainties unknown

Sensor	Expected Sensitivity (V/T)	Measured Sensitivity (V/T)
544	28.7	29.75
539	34.9	34.97
542	40.3	40.11
541	68.1	61.40

